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COMPOSITE MATERIALS BASED ON THERMOPLASTIC POLYMERS AND GLASS FABRICS

The possibility of making prepreg based on thermoplastic polymers and glass fabrics melt technology is shown. The effective permeability coefficients when impregnated fiberglass various thermoplastic binders is experimentally determined. The effect of the exponent in the law of flow of the polymer melt at the effective permeability is shows. The range of admissible parameters prepreg production process is calculated. Experimental samples through glass fiber prepregs and the thermoplastic polymers are made.

Introduction. During the recent years composited based on reinforced thermoplastic polymers become more and more used. The processes of receiving high-tension products from unidirectionally reinforced thermoplastic are well studied [1, 2]. The main disadvantage of unidirectionally reinforced composites and products is low tensile to perpendicular stratifils, which significantly limits the scope of use of such materials. Use as reinforcing agent of woven fabric (fiberglass, woven scrims, glass mats) will allow avoiding this disadvantage and expanding the scope of effective use of products made of reinforced thermoplastic.

Analogues of materials based on thermoplast and woven reinforcing material are well-known in the world. For example, Porcher Industries prepregs as binding, in which different thermoplastic polymers are used (polypropylene, polymeric amide, polycarbonate, polyurethane etc.), and as reinforcing material carbon, glass and aramid fabrics are used.

In the Republic of Belarus the processes of receiving composites based on thermoplasts and woven reinforcing material and also processes of receiving products on base of such materials are not enough researched. At the same time the subject matter is very urgent in connection with development of motor car and tractor construction, building etc., where such materials can be widely used.

Fiber-, film- and melt-impregnated technologies of material production on the base of thermoplastic and woven reinforcing material are known. During melt technology continuous woven reinforcing material is pulled through treating headpiece in which polymer melt from kneader is spread. After impregnation out it is possible to receive products with the help of forming device (one-step technology option) or material production (prepreg) in the form of coils or sheets, from which end-products are made by compression molding, thermal molding and pultrusion (two-step technology option).

The aim of the work is to estimate the possibility of prepreg production on the base of thermoplastic polymers and woven scrims and fiberglasss based on melt-impregnated technology.

Main part. To receive prepreg as thermofluid vehicle propylene Adstif HA5029 with melt flow index (MI) 40g/10 min and secondary polyethylene terephthalate were used. As reinforcing material structural fiberglass T10-80 All Union State standard 19170–2001 (JSC “Polotsk Steklovolokno”) with width of (80 ± 5) mm was used.

The diagram of preimpregnation on the base of woven reinforcing material by melt technology is shown at Fig. 1. Fiberglass from roll holder 1 is passed to impregnation die 2, in which melt of thermoplastic polymer is passed through extruder ЧП 32×25. Prepreg in calibration device 4 is calibrated and cooled. Prepreg pulled by a pulling device 6. After the prepreg can be rewinded into coils or cut to cut-to-length stocks.

The first process step – the impregnation – is quite well researched [2] for continuous fiber. Among the factors, determining the process parameters, are pore structure of reinforcing material, viscosity of matrix polymer, surface characteristics of components, pressure and duration of the effect. The conditions of complete impregnation out in the impregnation die; formation of sufficient for impregnation out polymer inlay are described by relevant dependencies between force F and drawing speed v:

$$F(v) = \mu \cdot R_p \cdot b \cdot h^{1+n} \cdot \left[(1+s) \cdot K_e \cdot \alpha \cdot \frac{R_p}{v} \right]^{-n}; \quad (1)$$

$$F(v) = \frac{\mu \cdot (2h_p \cdot R_p - h_p)^{0,5n} \cdot (s+2)^n \cdot b^{n+2} \cdot v^n \cdot R_p^{1-n}}{(n+2) \cdot h_p^{2n+1}}, \quad (2)$$

where μ is consistency index; R_p – round cells radius, where impregnation out us done; b – width of the woven reinforcing material; h – thickness of the layer wet out; n – index of power of melt flow law; $s = 1 / n$; K_e – effective permeation coefficient of fibrous layer; α – angle of wrap; h_p – thickness of polymer inlay; R – mandrel radius.

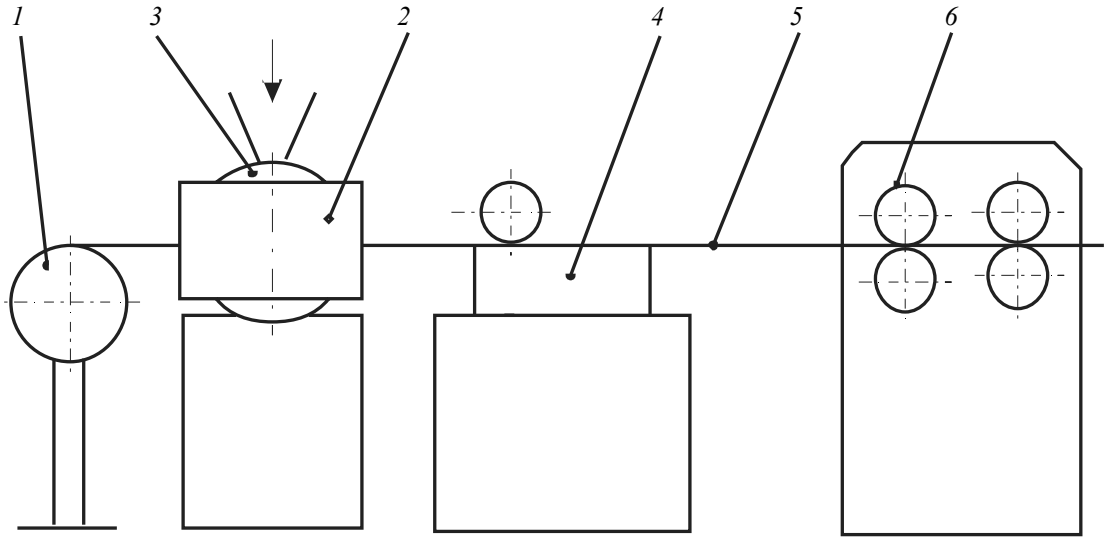

Fig. 1. diagram of preimpregnation on the base of fiberglass:
1 – roll holder with fiberglass; *2* – impregnation die; *3* – extruder; *4* – calibration device; *5* – prepreg; *6* – pulling device

Effective permeation coefficient in formula (1) was determined according to depth of thermoplastic polymer flowing into woven reinforcing material inlay. The diagram of depth determination is shown at Fig. 2. From fiberglass T10-80 discoid samples with diameter (50 ± 2) mm were preliminary cut out. From the cut out discs inlay 1 was formed, consisting of 5-7 discs. The inlay was fixed by paronite packing 2 from above and from below. At the bottom of the inlay steel net 3 with width of (1 ± 0,2) mm was fixed to reinforce fiberglass package. The received package was installed into bushing 4 and was screw fastened 5. The grommet with sample and hob 8 were placed into heated tablet-form framework 6. The temperature was controlled by thermocouple 7. The whole package was kept in the device until the necessary temperature was achieved.

Preliminary heated to the testing temperature in the chamber of the device IIRT-A polymer melt (volume 3–5 cm^3) was pressed out to bushing chamber *4*. As polymer coloured polypropylene and polyethylene terephthalate were used. Pressure for impregnation out was made by hob 8, on which loads with required mass were fixed.

After holding pressure time (t) the sample was removed, cooled and the depth of polymer flowing into woven reinforcing material inlay was determined by the amount of treated fiberglass layers. Effective permeation coefficient of fibrous layer was calculated according to the formula resulting from kinetic equation of impregnation out

$$K_e = \frac{h(t)^{s+1}\mu^s}{(1+s)p^s t}, \qquad (3)$$

where $h(t)$ is thickness of the layer wet out; p – pressure.

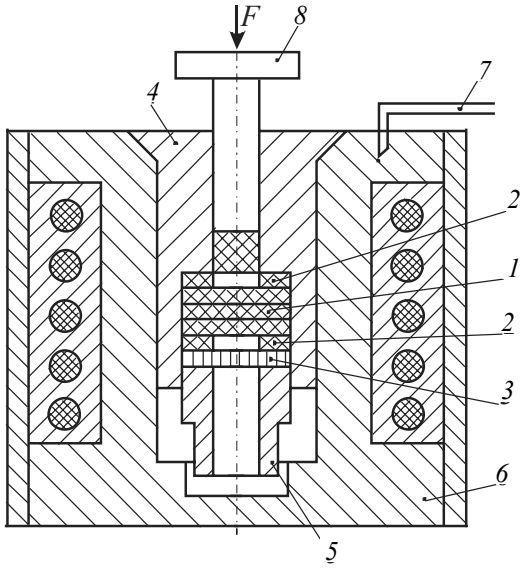

Fig. 2. Diagram of determination of effective permeation coefficient:
1 – fiberglass inlay; *2* – packing inlay; *3* – steel net; *4* – bushing; *5* – screw; *6* – tablet-form framework; *7* – thermocouple; *8* – hob

The results of the experiment are shown in the table.

From the table one can see that effective permeation coefficient practically does not depend on the pressure and holding time, but depends on index of power of matrix melt flow law.

The received value of effective permeation coefficient was used for calculation of valid parameters set of dipping process of fiberglass T10-80 with polypropylene and polyethylene terephthalate melt according to dependencies (2) and (3). The calculations have shown that the parameters of the dipping process of one layer of fiberglass with

width of 80 mm are limited only by dipping condition (2) (area above curves 1 and 2 in Fig. 3). At the mentioned width of fiberglass the inlay of polymer melt will be formed even under conditions exceeding fiberglass breaking weight. So, the condition of polymer inlay forming during preimpregnation on the base of woven reinforcing material with width more than 80 mm can be disregarded.

Table

Modes of effective permeation coefficient determination

Material	Pressure p_0, kPa	Temperature T, °C	Holding pressure t, s	K_e, 1 / m^{s+1}
Polyethylene	57	270	120	$1{,}9 \cdot 10^{-12}$
			240	$2{,}1 \cdot 10^{-12}$
			360	$2{,}1 \cdot 10^{-12}$
	115		120	$2{,}2 \cdot 10^{-12}$
	140		120	$2{,}3 \cdot 10^{-12}$
Polyethylene-terephthalate	30	280	180	$1{,}8 \cdot 10^{-12}$
	30		120	$1{,}7 \cdot 10^{-12}$
	115		120	$1{,}5 \cdot 10^{-12}$

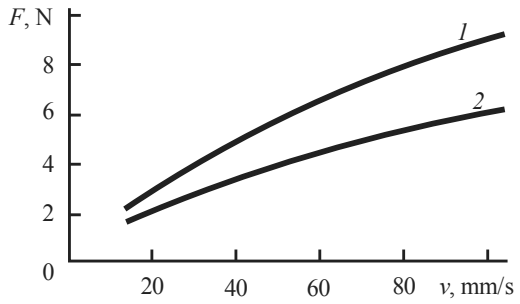

Fig. 3. Parameters of fiberglass dipping process T10-80 with polymer melts: *1* – polyethyleneterephthalate; *2* – polypropylene

Using the calculated process parameters (Fig. 3) according to diagram from Figure 1 prepreg samples based on polypropylene and polyethyleneterephthalate were received. The photo of prepreg based on fiberglass T10-80 and polypropylene is shown in Fig. 4.

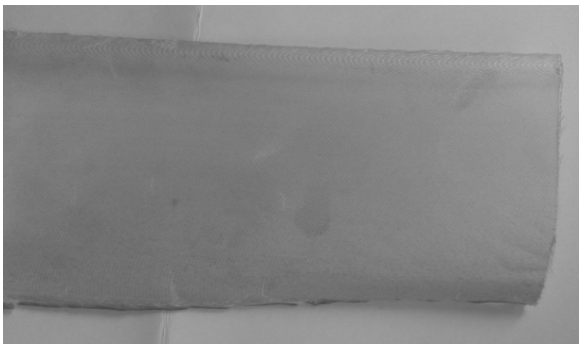

Fig. 4. Prepreg based on fiberglass T10-80 and polypropylene

Conclusion. On the base of experimental data to determine permeation coefficient valid parameters set of preimpregnation on the base of T10-80 fiberglass with such polymer as polypropylene and polyethylene terephthalate was calculated. The possibility of receiving such materials was shown.

References

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